

EFFECT OF NOZZLE DESIGN ON THE
COEFFICIENT OF EFFLUX OF AUTOMATIC SPRINKLERS

BY

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ARMOUR INSTITUTE OF TECHNOLOGY
1911

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THE EFFECT OF NOZZLE DESIGN ON THE COEFFICIENT OF EFFLUX OF AUTOMATIC SPRINKLERS

A THESIS

PRESENTED BY

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ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY

FIRE PROTECTION ENGINEERING

1911

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PREFACE.

Through the Underwriters' Laboratories, (1207 E. Ohio Street, Chicago, Illinois,) twenty-nine especially made automatic sprinklers were obtained for this work. A set of preliminary tests were first run to determine the best method of attacking the subject. There were many opportunities for error in the test work, but it can safely be said that any error will not be greater than 2%.

We are greatly indebted to the Underwriters' Laboratories, Inc., where the work was conducted for the means of carrying out these tests, also to Professor Fitzhugh Taylor and C. R. Alling, Assistant Engineer for their advice.

H. M. A.

M. E. D.

E. C. D.

INTRODUCTION.

An automatic sprinkler is a mechanical device designed to operate when subjected to a given high temperature, and thus permit the discharge of water from a piping system. It is opened by heat acting on a low fusing point solder and is provided with a means of throwing the cap and loose parts out of the path of the water. (This may be done by means of a spring or by the strain in the frame.) The part considered in this thesis is the nozzle or the base of the sprinkler through which the water passes before reaching the seat. (See Fig's. 3 and 6.)

The object of the thesis was to find the effect of different designs of nozzles on the discharge coefficient of automatic sprinklers.

PRELIMINARY TESTS

THE OBJECT:-

The object of the preliminary tests was to determine whether or not the wet head had any effect on discharge as the other heads on the same sprinkler line.

DESCRIPTION OF APPARATUS:

The water for these tests was supplied by two electrically driven pumps of 500 and 50 gallons per minute capacity respectively. Some idea of the piping scheme can be obtained from Figure #1. But instead of a 10 ft. length of horizontal piping as shown in the Figure, a 20 ft. length was used. This consisted of two 10 ft. lengths of 1 inch and 3/4 inch piping, the former being joined to the 2 inch supply pipe just beyond a gate valve. The two lengths of piping were connected by a standard sprinkler tee (1 x 3/4 x 1/2 inch) and the end of the smaller pipe equipped with a standard ell (3/4 x 1/2 inch). Two similar sprinklers placed in the ell and tee completed the system.

A brass pipe about 12 inches long was placed in the 1 inch pipe line just ahead of the tee, with a piezometer ring connection near the end. A 1/2 inch mercury manometer was used to read pressures up to 25 lbs.; a hose leading from this gauge to the piezometer ring. A 100 lb. Bourdon gauge (calibrated) was placed on the top of the manometer so that it could be used to read pressures above 25 lbs., by merely closing the manometer.

A 250 gallon measuring tank (See Figure #1) was used to measure the discharge, readings being estimated to the 1/10 of a gallon. (This had been previously calibrated). A galvanized iron hood was placed over the head in order to confine and direct the water downward

METHODS EMPLOYED:-

For convenience the end sprinkler was called "A" and the other "B". A series of tests were first run (Test #1) in which both sprinklers were open, the discharge and pressure (at piezometer) being measured. Ten readings were taken, the pressure varying from about 5 pounds to 60 pounds at 5 pound intervals. By means of a wing joint near the valve, the head was pushed over the measuring tank and allowed to discharge for two minutes, the time being taken by a stop watch. The pressure in the large pressure tank was kept at 125 pounds, and for the first five or six readings this source of supply was used alone, but for the higher pressures it was necessary to start the small pump. The desired pressure was obtained by throttling the water supply at the gate valve previously mentioned. A test was not started until the flow was constant as indicated by the steadiness of the gauge. A constant pressure was obtained by discharging the larger pump against an air cushion in a 4500 gallon pressure tank, and bleeding the water off, and at the same time allowing the small pump to discharge directly into the piping. For the lower pressures, better results were obtained by using water from the tank alone. Great care was exercised to see that all the air was out of the manometer before it was used. All observations of the discharge were checked at least twice, or until three of the values came within 1% of each other.

Having obtained the rate of discharge from "B" with "A" open, the discharge from "A" was obtained at the same pressure (Test #2) in order to obtain the total quantity flowing through the 1 inch piezometer. These values were used in calculating the velocity pressure. The third test was run with "B" open and "A" closed the same observations of pressure and discharge being noted, finally a set of readings were taken with "B" closed and "A" open, to determine whether or not the discharge from an ell was different from that of a tee under the same conditions.

CALCULATIONS:-

1 inch of mercury = 1 inch of water = .454 pounds per sq. in.

Diameter of piezometer pipe = .61/.64 inch.

APPENDIX (II)

Observed pressure = 9.9 inches of mercury.

$$9.9 \times .454 = 4.49 \text{ pounds per sq. in.}$$

Test 1. Observed gallons per minute (average) = 11.7 (Page 20)

Appendix

"	2.	"	"	"	"	"	=	10.56
Total	"	"	"	"	"	"	=	22.28

$$\text{Velocity pressure} = .001126 \frac{Q^2}{d^5}$$

Where Q = discharge in gallons per minute
d = diameter of pipe in inches.

$$\text{Velocity pressure} = .001126 \frac{(22.28)^2}{(61/64)^5}$$

$$= .677 \text{ pounds per sq. in.}$$

$$\text{True pressure} = \text{velocity pressure} + \text{static pressure.}$$

$$= 4.49 + .677 = 5.167$$

In this way the true pressure was obtained, and the test was plotted on conclusion, against the discharge as above. This was done for Tests 1, 3 and 4. See Pages 5 and 6 in Appendix.

CONCLUSIONS:-

By comparison of the curves of these tests it was found that they practically coincide, showing that the discharge from head "B" is practically the same as from "A", at the same pressure. Further comparison shows the curve for Test #4 to be the same as for Test #2, which means that the eddying in the ell has no appreciable difference from that in the tee.

It was, therefore, decided to run the tests on the special heads in position "A" with "B" shut off, merely for the convenience of handling the pipe, as the 10 ft. length of 1 inch piping could be left out.

TESTS ON SPECIAL HEADS

DESCRIPTION OF APPARATUS:-

HEADS:- Tests were run on two different types of heads, namely the Orinelli, made by the General Fire Extinguisher Co. of Providence, R. I., and the manufacturers made by the Automatic Sprinkler Co. of America, New York, New York. Seven special heads were made by the former company varying in the inlet diameter only (dimension A Fig. 3, page 2 Appendix). (Sections of the base of these heads are shown in Fig. 4, page 3 Appendix. Dimensions are given in Appendix, page #34.) The same frame and diaphragm were used in all the tests to avoid any variation in discharge due to these parts. Twenty-two special Manufacturers heads were made, part of which varied in inlet diameters and part in the width of the collar forming the ring nozzle. (Dimensions B and D in Fig. #6, page 4 Appendix. The dimensions of these heads are given in Appendix page #34.)

The pumps, gauges, and measuring tank were the same as used in the preliminary tests and described on page 43. The piping consisted of the 3/4 inch length (10 ft. 1 in. including the piezometer connection) extending out from the wall as shown in Fig. #1. The heads were screwed into place in a 3/4 x 1/2 inch reducing elbow in the end of the pipe as previously done.

METHOD EMPLOYED:-

The method employed was similar to that used in the preliminary tests, namely the pressure was adjusted and allowed to become constant, and the head pushed over the measuring tank for a 3 minute run. Ten observations were taken, at pressures ranging from 5 to 50 lbs. at 5 lbs. steps. (The lower pressures were approximated on the mercury gauge). At least three sets of readings were taken for each pressure, and more if they did not check within 1%.

The velocity pressure was calculated, to get the true pressure. Curves were plotted, with pressure as ordinates and discharge in gallons per minute as abscissae. The coefficient of efflux was calculated, for each of the heads.

CALCULATION:-

Piezometer pipe diameter = 15/16 inch.

Pressure in inches of mercury (observed) = 10.4 (Page 24)

" pounds per square inch = $10.4 \times .454 = 4.73$

Gallons per minute = 15.55

Velocity pressure = $\frac{.0008 Q^2}{Y^5}$ (Page 10)

= .625

True pressure = $.625 + 4.73 = 5.355$ lbs. per sq. in.

Coefficient of efflux =

$$\frac{C_d \cdot P \cdot \pi \cdot d^2}{4 \cdot \pi \cdot r^2 \cdot Y^5}$$

$$\frac{Q \text{ (gals per min)} \times .13368 \times 12.87}{4 \times \pi \times r^2 \times Y^5}$$

$$\frac{.0008 Q \text{ (gals/min)}}{Y^5 \text{ (in)}^5 \sqrt{H \text{ (ft)}}}$$

$$= \frac{.0008 Q \text{ (gals/min)}}{Y^5 \text{ (in)}^5 \sqrt{H \text{ (ft)}}}$$

r = radius of pipe.

Gallons per minute = 15.55

r = .251 inches.

$$= \frac{.0008 Q \times 15.55}{(.251)^5 \times 5.355}$$

CONCLUSIONS:-GRINNELL HEADS.

The inlet diameter being the only variable dimension in the Grinnell heads, any difference in the curves or coefficients can be laid to this fact alone. Upon inspection, the discharge curves seem to vary inversely as the inlet diameter; that is the sprinkler with the largest inlet diameter has the smallest delivery and conversely the sprinkler with the smallest diameter has the largest flow. This relation is not constant for several heads dispute this relation.

The coefficient of efflux seem to vary to such an extent that no conclusion can be drawn. The coefficients for each head seem to reach a maximum at the first reading, gradually drop and finally rise a small amount.

MANUFACTURED HEADS.

By comparison of the curves of the several heads, it is found that the discharge has a tendency to decrease, as the inlet diameter increases. In the five heads, which have a common width of collar, and a varying inlet diameter the coefficient of efflux varies as follows:-

<u>No. of head</u>	<u>Inlet diameter</u>	<u>Discharge coefficient</u>
7	.532"	.762
8	.548"	.713
3	.530"	.692
11	.562"	.686
2	.590	.677.

It can be readily seen that the coefficient drops as the inlet diameter increases.

Seventeen of these heads had a constant inlet diameter with a varying length of collar. Studying the curves, it is seen that the discharge increases as the length of collar increases. The coefficient of efflux has a tendency to increase with the length of collar, although it is not constant. The coefficient of efflux also varies as the pressure on any one head. This relation is also very uncertain, the curve being very erratic for every head. (For this reason the curves were not plotted).

The peculiar thing noted in these curves is the way five of them drop down when a certain pressure is reached. Upon investigation it was found that these five curves dropped consecutively along the curve and that the length of collar was proportionally longer. These five curves were plotted on one sheet (See page #19a- Appendix) to show more clearly the phenomena. They all seem to start about the same point and finish together. A reason for this action was looked for and it was decided that this drop in discharge at a certain pressure was due to the edge of the jet leaving the wall of the nozzle. So accordingly as the length of the collar was increased, it would require a higher pressure to make the jet to flow without touching the nozzle which was shown to be true by the curves. This being the case, why did not the other heads show this phenomena? Upon examining

dimensions further it was noted that the other heads (exclusive of the five previously mentioned) had longer or shorter collars. It was decided that the sprinklers with the shorter collars would have shown this action if careful observations had been taken at low pressures (below five pounds), and the heads with longer collars would have shown it if higher pressures had been used (above 50 pounds). To show this a curve was plotted (page #19) with pressures as abscissas and length of collar as ordinates. The pressure taken was the point at which it appeared to drop off, which was not very definite. If more readings had been taken at lower and higher pressures this curve would have been more definitely defined. As it is, however, it appears from the curve that the inlet diameter would govern the discharge at a pressure of 25 lbs. if no collar was present. Over twice this pressure is very often obtained in high buildings. Because of lack of time, this work could not be more fully carried out, but it leads to conclusion that all the heads would show this dip if complete tests were run.

XXXXXXXXXX



Fig. 1.

The Grinnell Sprinkler Head.



Fig. 2.



Fig. 3.

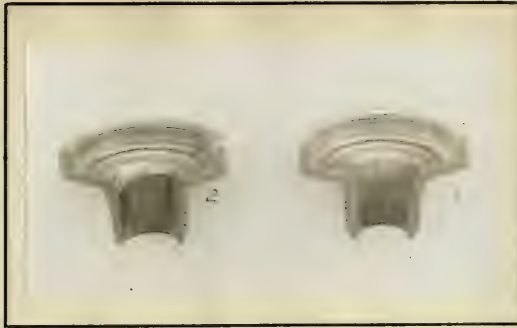


Fig. 4.

The Manufacturers Sprinkler Head.



Fig. 5.

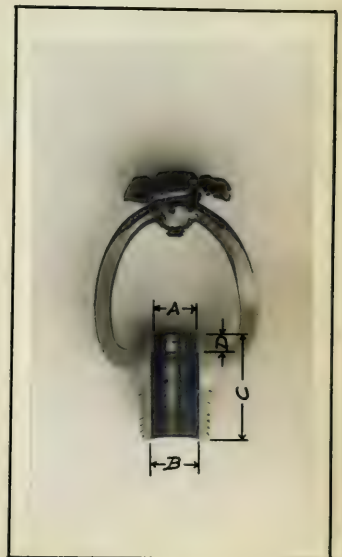
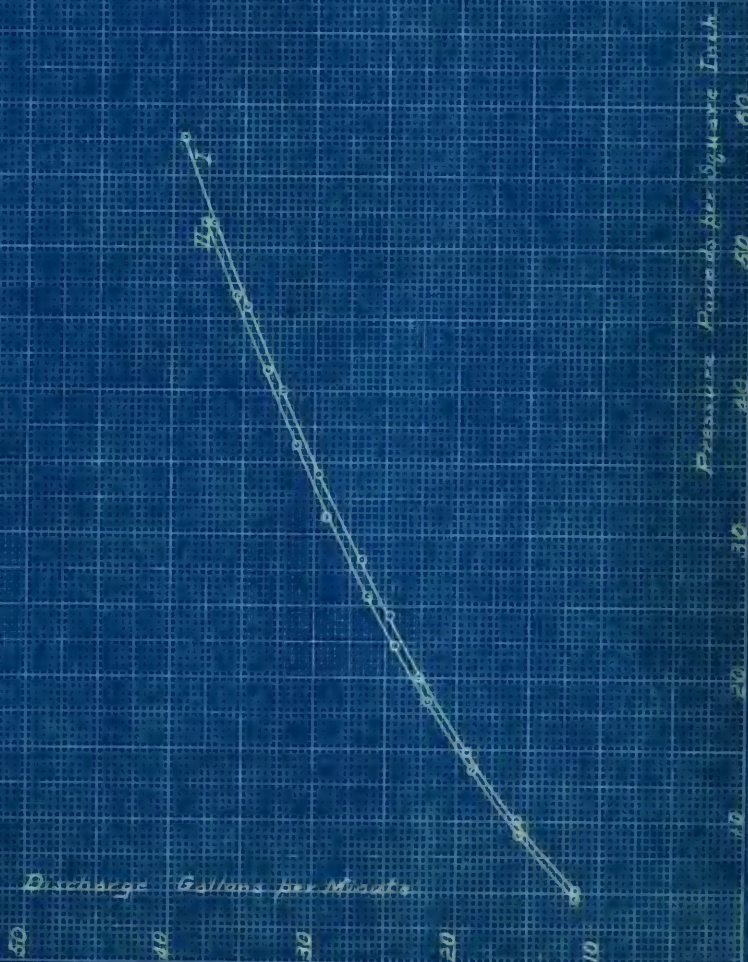


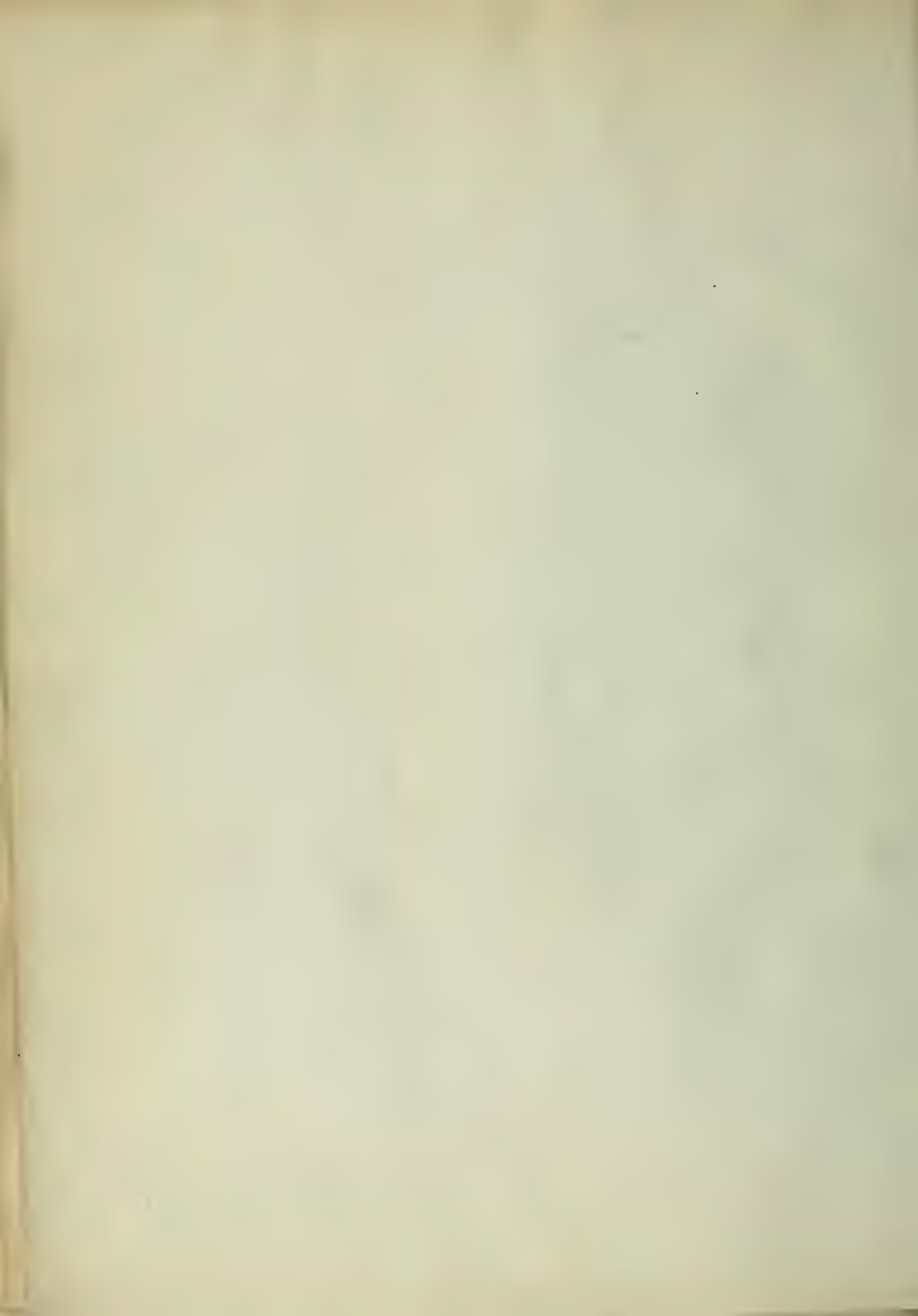
Fig. 6.



Graphs I - B with A open
" II - B " A closed

Standard Oil Company, Inc.

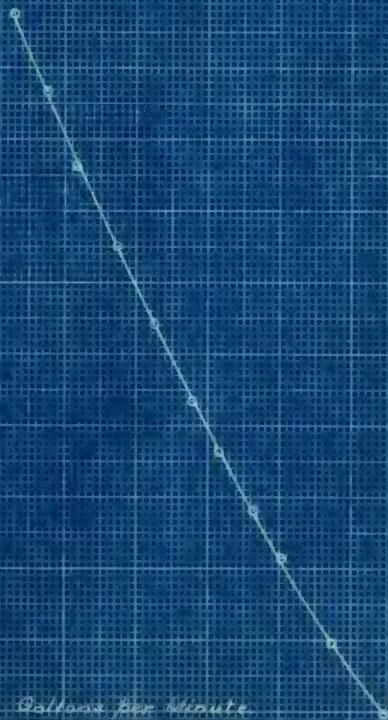
Tests No. 1 and 3



Discharge Gallons per Minute

Pressure Pounds per Square Inch

A with B closed
Standard Brinell Head
Test No. 4

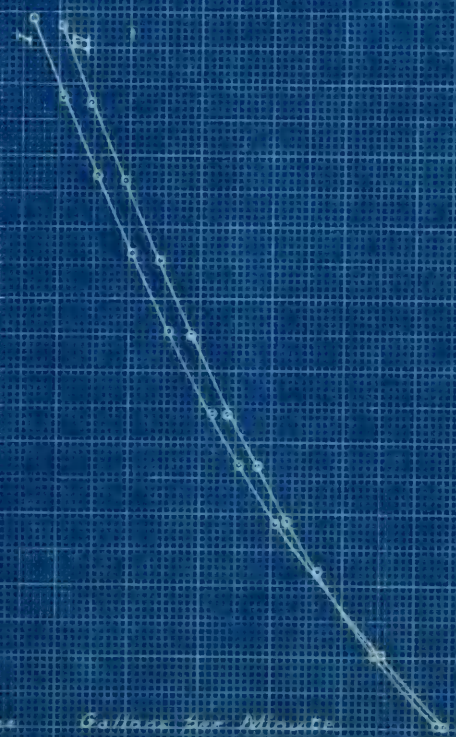


Discharge Gallons Per Minute

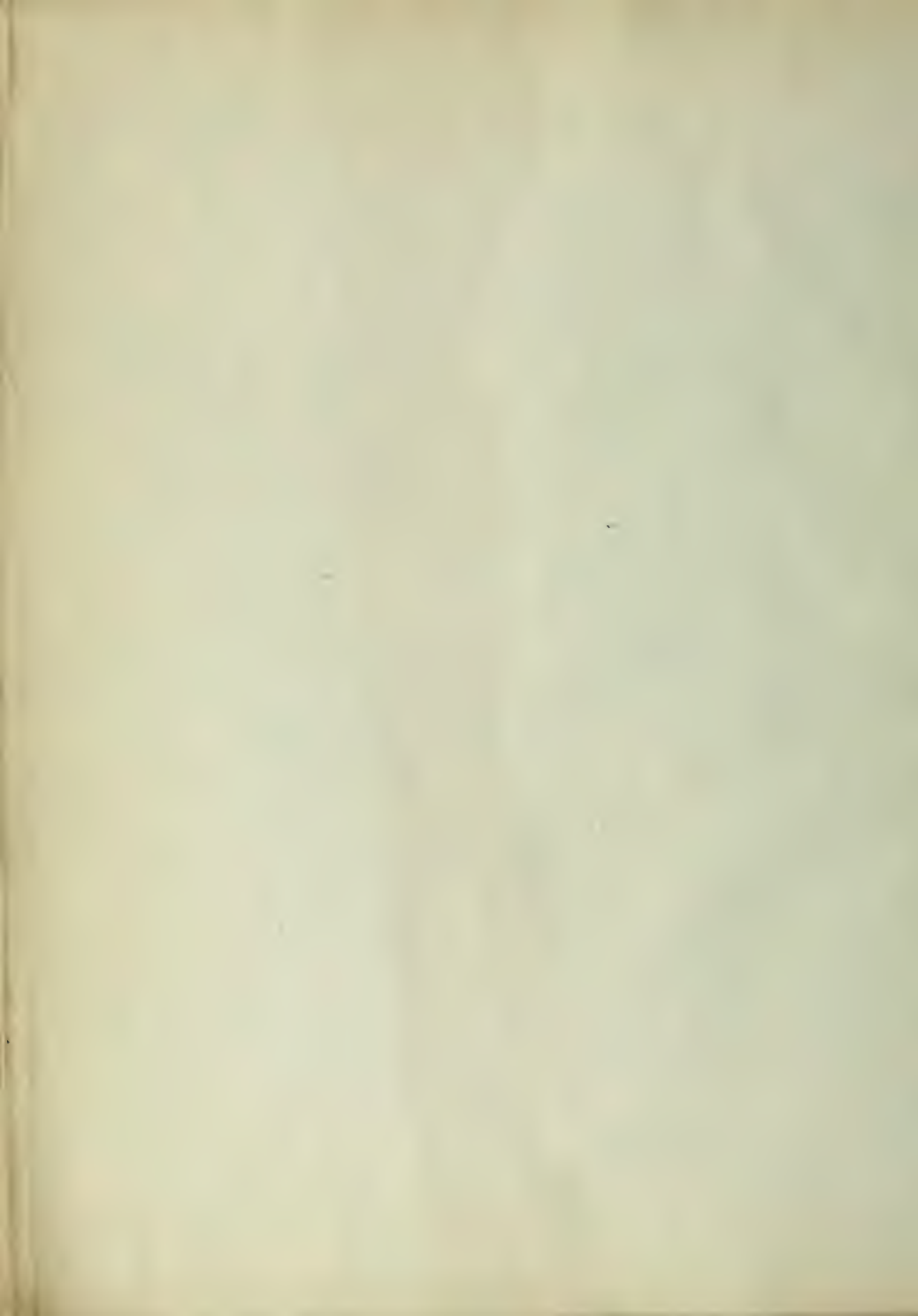
50
40
30
20
10

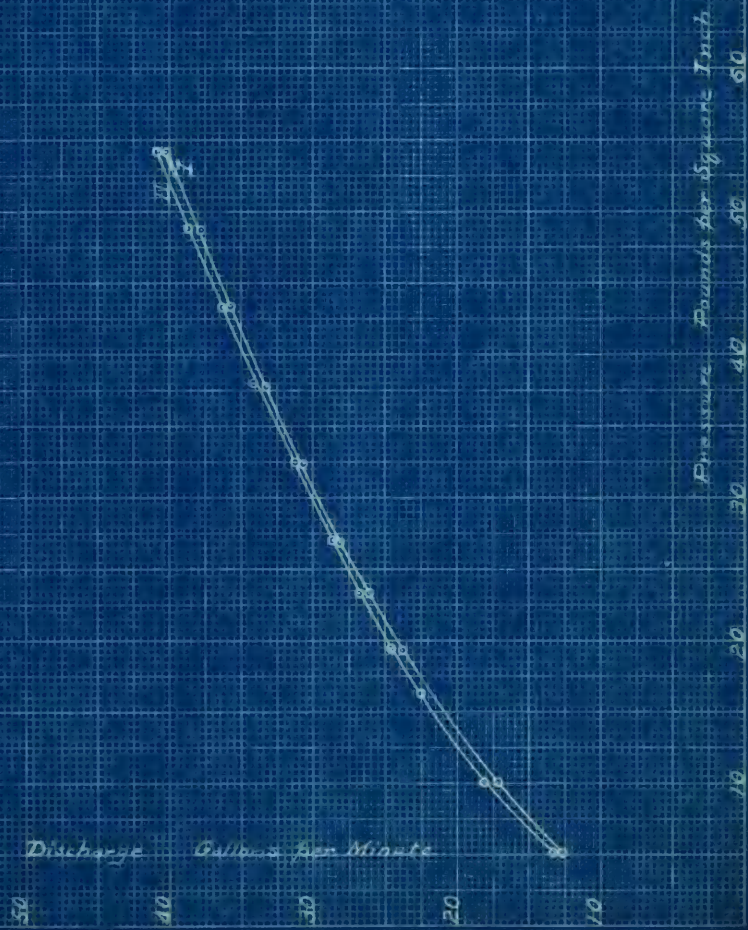
Pressure Pounds Per Square Inch

60
50
40
30
20
10

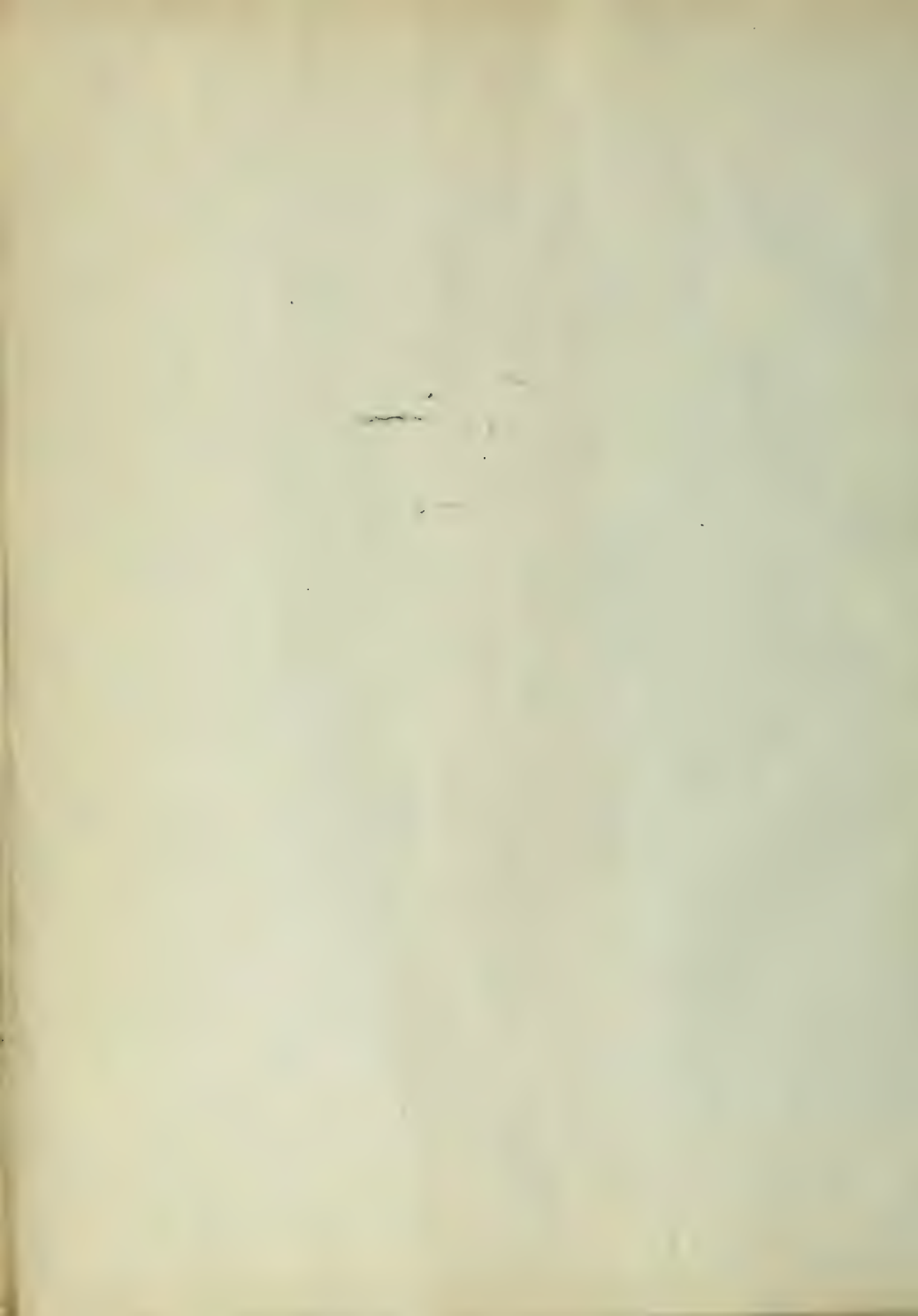


Curve I - Control No. 1
" II - " 2





Curve I - Standard
 " II - 15

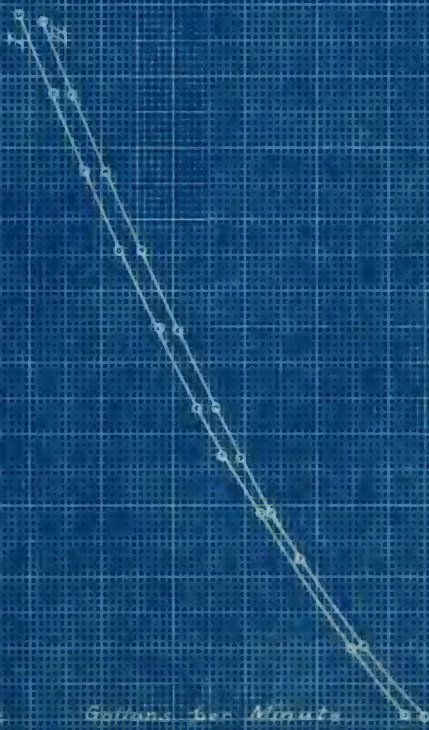


Discharge

Galons per Minute

Pressure Pounds per Square Inch

Curve I - Grinnell #5
" II - " " #8



Discharge

Gallons per Minute

Pressure Head, feet Square Inch

Graph 11

50

40

30

20

10

0

10

20

30

40

50

60

70

80

90

100

110

120

130

140

150

160

170

180

190

200

210

220

230

240

250

260

270

280

290

300

310

320

330

340

350

360

370

380

390

400

410

420

430

440

450

460

470

480

490

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510

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940

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1060

1070

1080

1090

1100

1110

1120

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1160

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1200

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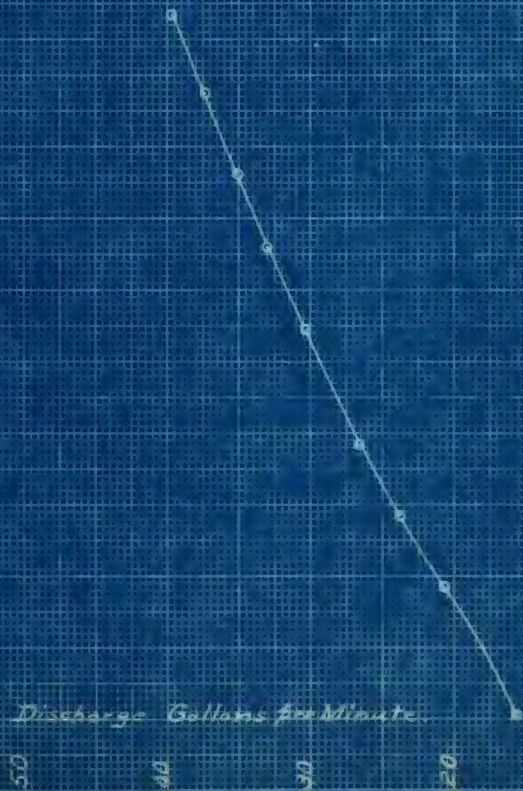
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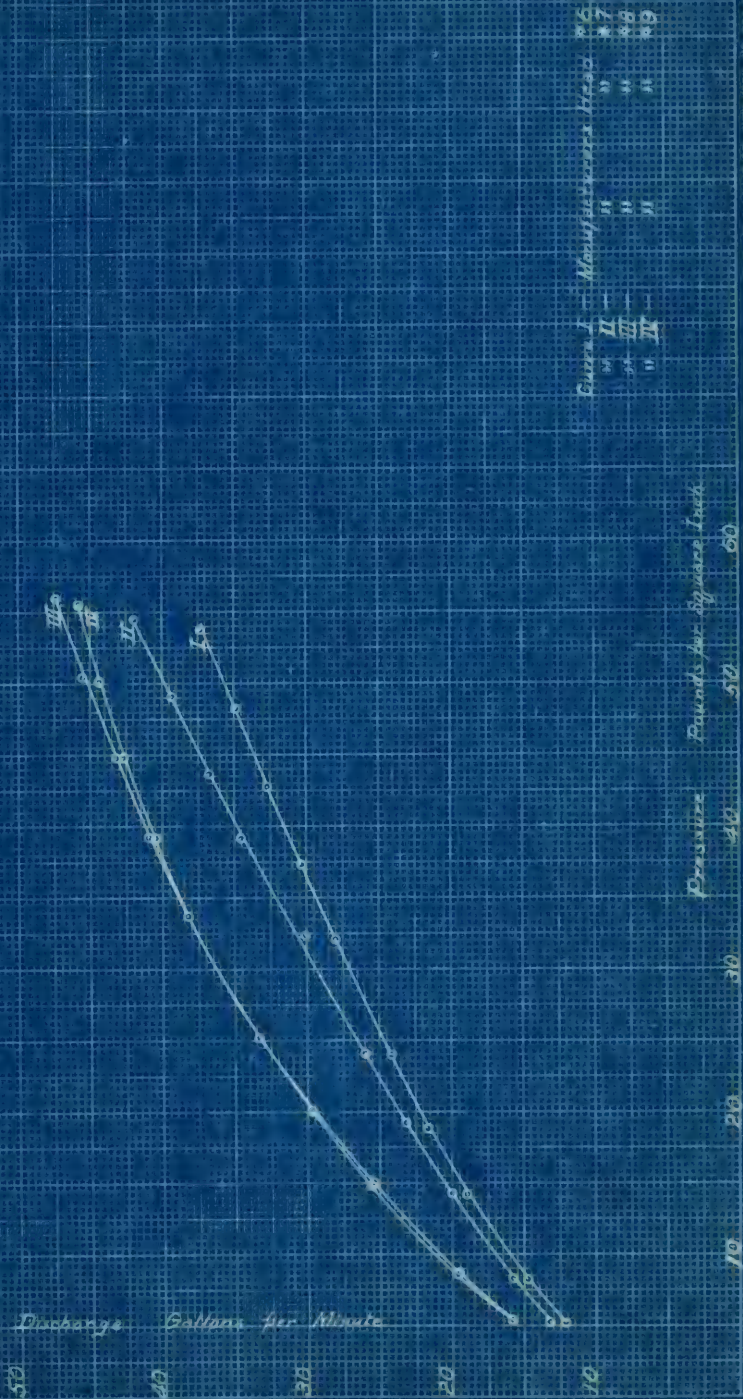


Discharge Gallons per Minute

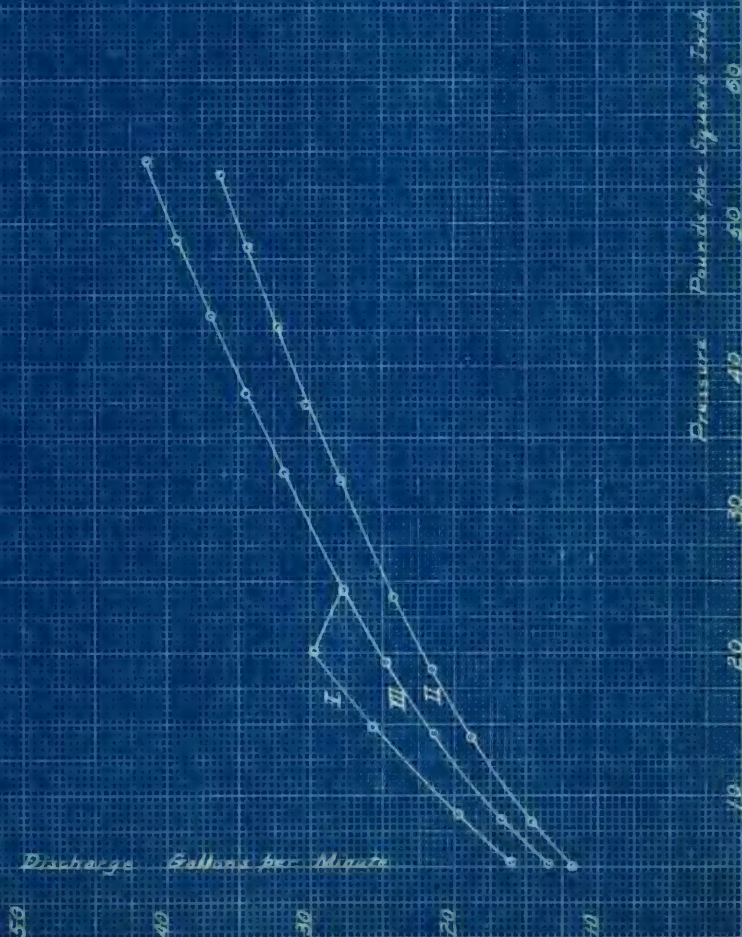
Pressure Pounds per Square Inch

Experimental Manifolds
Fitted with
Standard Abrasive Design





Curve I — Manometer Head 1.6
 II — " " 1.7
 III — " " 1.8
 IV — " " 1.9

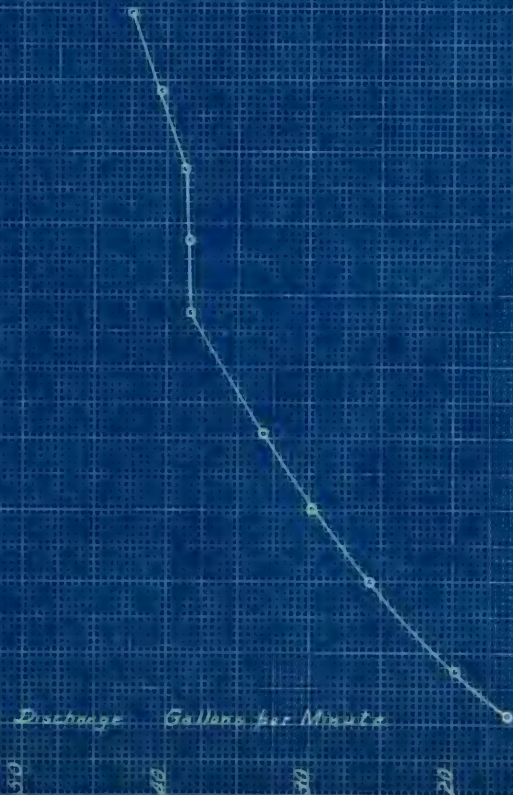


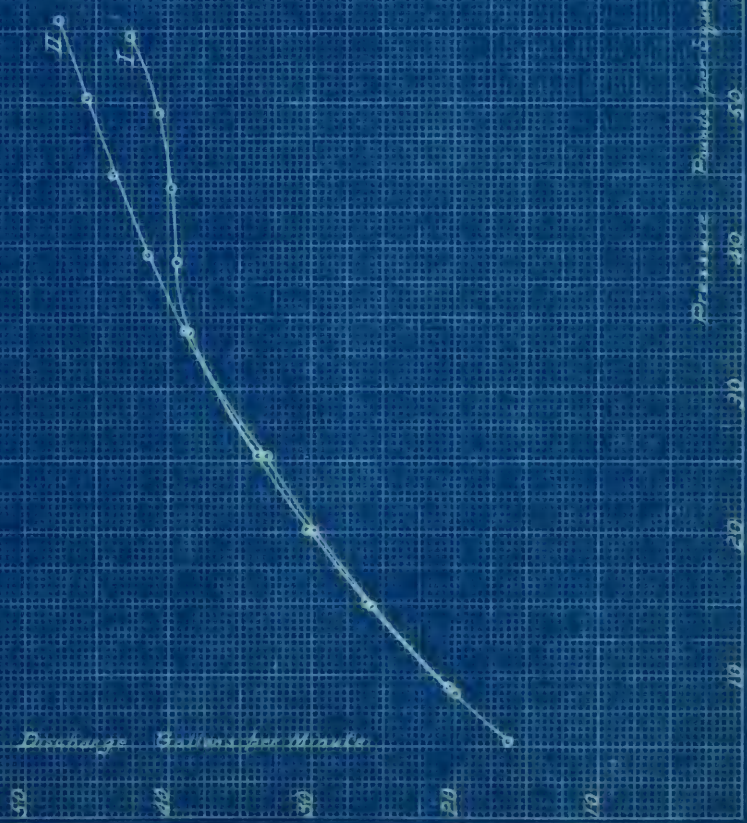
Curve I - Manufacturers Head #10
 II - #11
 III - #12

Discharge Gallons per Minute

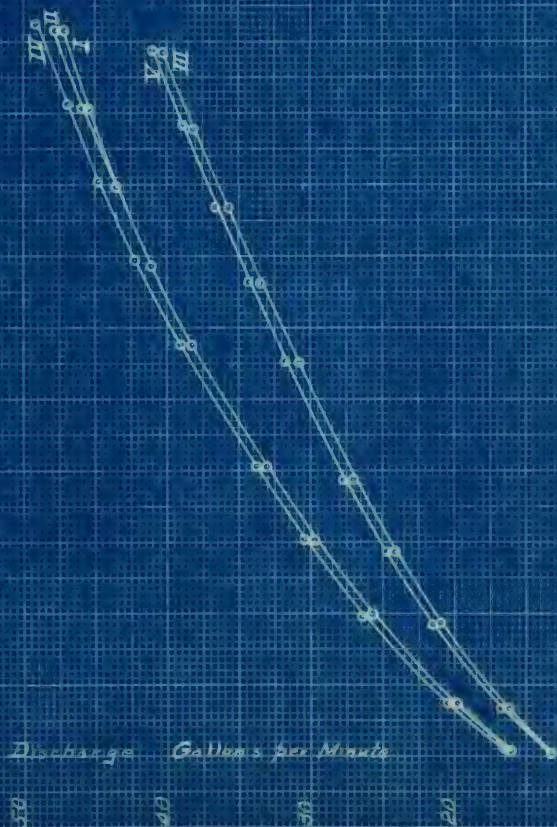
Pressure Pounds per Square Inch

Manometer Head 2.5

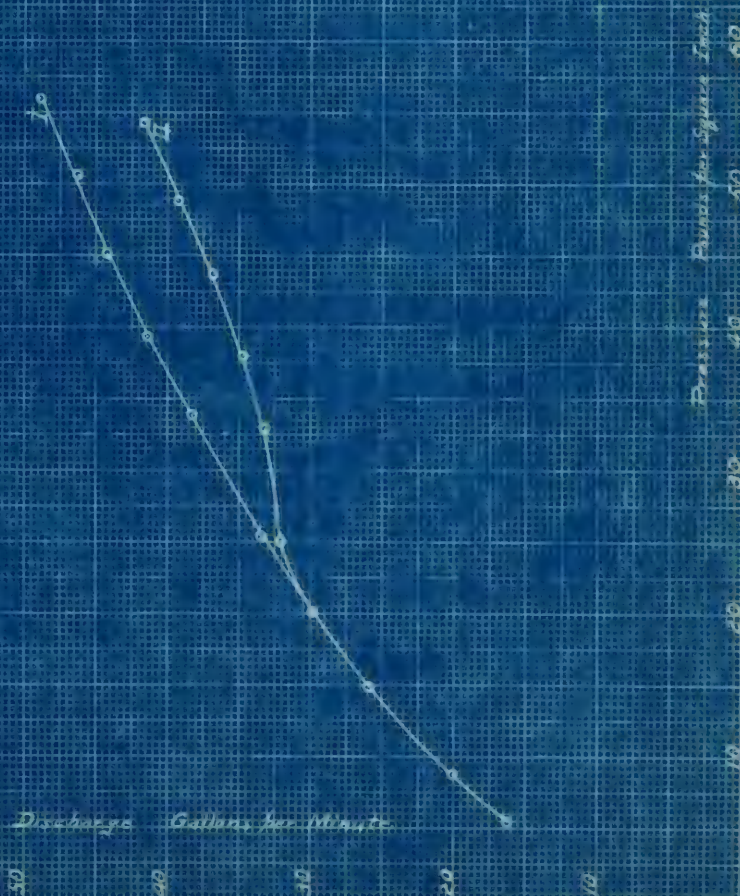




Curve I - Manufacturer's rating with
 " " " " " "

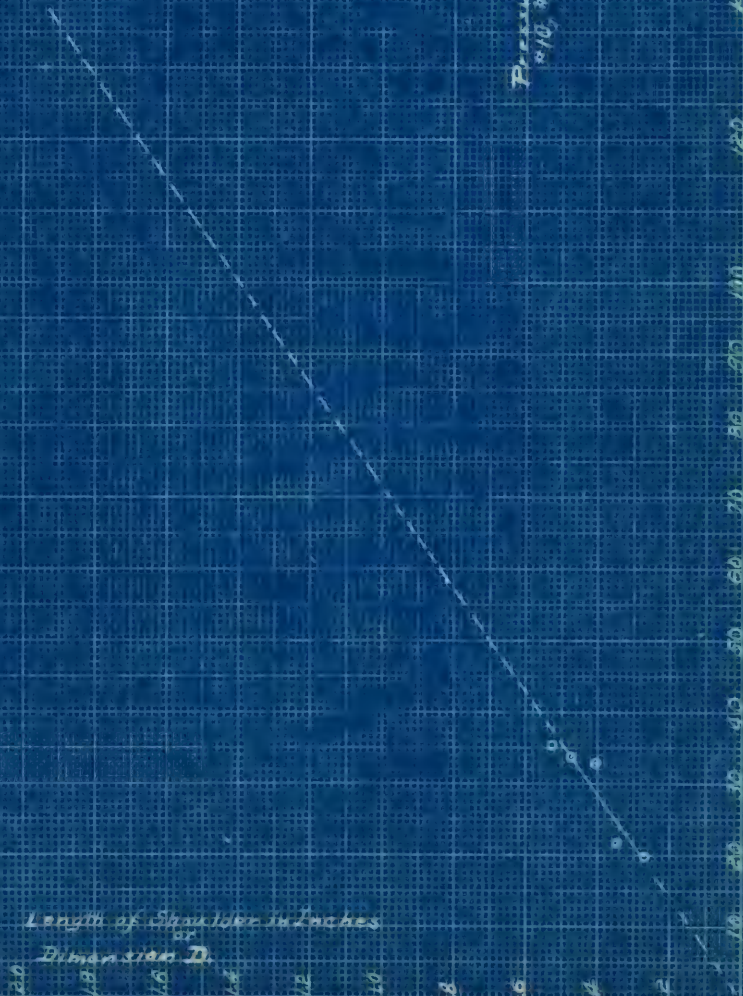


Curve	I	II	III	IV	V
Manifolds Head	16	17	18	19	20
ft	37	38	39	40	41



Curve I - Manufacturer's Data
 Curve II - Test Data

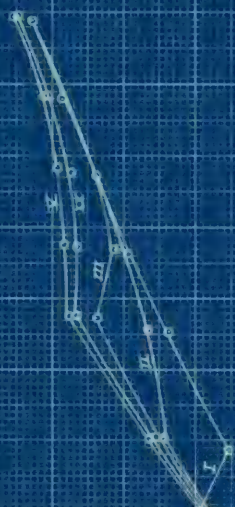
Length of Shankle in Inches
 Dimension D.



Pressures from Manufacturers' Heads
 #10, #22, #5, #13, #14, at which the
 Drap occurs.

Discharge Gallons per Minute

Pressure Pounds per Square Inch



Comparison of Curves
Showing Aberration

Curve	# I	# II	# III	# IV	# V
Manifolds	100	100	100	100	100

Test No. 1.

PRELIMINARY

Test No. 2.

Gauge	Press.	Discharge from B With A Open			
		Gallons/2 Minutes		per Min.	
		1st.	2nd.	3rd.	Aver.
9.30 Hg.		23.25	25.50	33.50	23.41
19.30 "		32.00	31.25	31.50	31.58
29.30 "		38.25	38.75	39.00	38.65
39.30 "		45.50	45.25	45.00	45.25
47.30 "		50.25	49.25	49.20	49.56
54.35 "		53.50	53.50	---	53.50
59.50	59.75	---	---	---	59.62
60 lba.	30 lba.	64.75	64.50	---	64.65
35 "	40 "	69.25	70.25	69.25	69.58
40 "	45 "	74.50	74.00	---	74.25
45 "	50 "	80.00	77.50	78.00	78.50

Total Gals./Min. A plus B	Gauge	PRESSURE		
		sq. in.	lbs. per sq. in.	Velocity lbs./sq. in.
23.28	9.36/Hg.	4.49	.677	8.167
28.99	19.60 "	8.90	1.144	10.044
35.53	29.20 "	13.23	1.715	14.965
42.08	39.10 "	17.75	2.405	20.155
46.60	47.20 "	21.45	2.954	24.404
50.45	54.35 "	24.75	3.460	28.310
56.26	30 lbs.	30.00	4.319	34.319
61.44	35 "	35.00	5.140	40.140
65.95	40 "	40.00	5.920	45.920
70.17	45 "	45.00	6.590	51.690
75.15	50 "	50.00	7.680	57.680

PRELIMINARY DATA. (continued). Test No. 3.

Discharge from B with A closed

DISCHARGE

PRESSURE

Gallons per Minute			Gals. per Minute		lbs. per sq. in.		Velocity lbs./sq. in.		True lbs./sq. in.	
Int.	30s.	1mi.	Aver.	Int.	30s.	1mi.	Int.	30s.	1mi.	Int.
23.50	24.8	21.40	25.03	11.51	9.90	8g.	4.49	.180		4.670
31.00	31.34	31.30	31.16	15.58	19.60	"	8.90	.330		9.230
37.70	37.70	37.30	37.73	18.86	39.30	"	13.25	.484		13.734
44.00	44.30	44.30	44.02	23.01	39.10	"	17.75	.661		18.411
48.40	48.15	48.40	48.30	24.45	47.30	"	21.45	.815		22.265
52.50	52.45	52.70	52.55	26.27	54.55	"	24.75	.941		26.691
58.40	58.30	58.70	58.66	29.33	30 lbs.		30.00	1.171		31.171
62.60	62.50	62.80	62.65	31.32	35 "		35.00	1.336		36.336
66.75	66.50	66.50	66.58	33.29	40 "		40.00	1.510		41.510
72.50	72.50	71.10	72.76	35.38	45 "		45.00	1.704		46.704
74.90	75.00	76.10	75.00	37.50	50 "		50.00	1.915		51.915

Standard Grinnell Head.

Discharge from A with B closed

Test No. 4.

Coefficients of Discharge.

25.50	35.00	25.30	25.30	12.65	10.00	Hg.	4.54	.413	4.953
32.70	33.00	33.10	32.93	16.45	20.00	"	9.08	.700	9.780
39.30	40.00	39.90	39.73	19.85	32.70	"	14.85	1.020	15.870
45.50	43.80	43.30	43.53	21.76	39.45	"	17.93	1.321	19.141
48.50	48.60	48.80	48.63	24.31	47.60	"	21.53	1.526	23.156
52.00	52.20	52.10	52.26	26.13	54.80	"	24.92	1.751	26.681
58.00	58.00	57.50	57.83	28.91	30 lbs.		30.00	2.160	32.160
62.50	62.60	63.60	63.56	31.38	35 "		35.00	2.528	37.528
68.70	68.90	68.20	68.60	34.30	40 "		40.00	3.040	43.040
72.20	72.70	73.40	72.43	36.21	45 "		45.00	3.393	48.383
76.90	77.30	77.00	77.06	38.53	50 "		50.00	3.830	55.830

1st.	2nd.	3rd.	Aver.	Gals. per Minute
25.8	26.0	25.9	25.90	12.95
34.9	35.0	---	34.95	17.47
49.3	49.7	---	49.50	24.75
54.5	55.0	54.5	54.66	27.33
58.0	58.4	58.3	58.23	29.11
64.3	---	---	64.30	32.15
69.5	70.0	70.0	69.83	34.91
75.0	74.6	74.6	74.73	37.36
79.8	79.1	80.0	79.63	39.81
83.8	83.3	83.4	83.70	41.85

GRINNELL NO. 2

26.6	26.4	---	26.50	13.25	10.4" Hg.	4.725	.454	5.179	.780
35.0	34.9	35.3	35.08	17.54	20.4" "	9.370	.795	10.065	.740
43.5	43.8	44.0	43.73	21.86	33.0" "	14.980	1.338	16.223	.735
47.9	48.0	48.1	48.00	24.00	39.4" "	17.890	1.489	19.387	.730
52.1	52.3	51.5	52.00	26.00	47.5" "	21.560	1.746	23.306	.721
56.2	56.7	55.7	56.53	28.26	54.8" "	24.900	2.065	26.965	.728
61.5	61.1	61.3	61.30	30.65	30 lbs.	30.000	2.430	32.430	.731
66.0	65.8	66.0	65.93	32.96	35 "	35.000	3.803	37.803	.716
71.1	70.7	70.8	70.86	35.43	40 "	40.000	3.350	43.350	.732
75.7	74.9	75.7	75.43	37.71	45 "	45.000	3.673	48.673	.724
79.7	80.0	79.3	79.63	39.81	50 "	50.000	4.090	54.090	.715

GRINNELL NO. 3

25.2	25.4	25.8	25.46	12.73	10.4" Hg.	4.725	.419	5.144	.751
34.8	34.3	---	34.55	17.27	20.4" "	9.370	.770	10.040	.738
47.8	47.2	47.8	47.60	23.80	39.4" "	17.890	1.464	19.354	.725
52.3	52.4	52.5	52.40	26.20	47.5" "	21.560	1.773	23.533	.726
56.2	56.6	55.9	56.23	28.11	54.8" "	24.900	2.040	26.940	.725
61.2	61.3	60.9	61.30	30.65	30 lbs.	30.000	2.430	32.430	.721
66.2	65.9	66.3	66.45	33.23	35 lbs.	35.000	2.860	37.860	.733
71.3	71.9	71.3	71.50	35.75	40 "	40.000	3.300	43.300	.737
75.8	75.0	76.0	75.93	37.96	45 "	45.000	3.719	48.719	.733
80.3	80.4	80.6	80.45	40.23	50 "	50.000	4.180	54.180	.730

Post-Exhibents
 of
 Discharge.
 .747
 .760
 .745
 .745
 .742
 .735
 .733
 .742
 .733
 .745
 .744

PRESSURE		
Gauge	Lbs. per sq. in.	True lbs./sq. in.
10, 1 1/2 in.	4.725	5.177
20, 2 in.	9.720	10.122
30, 3 in.	14.990	16.295
33, 3 1/2 in.	17.890	19.448
47, 5 in.	21.560	23.418
54, 5 1/2 in.	24.900	27.000
50, 30 lbs.	30.000	32.515
35, "	35.000	38.025
40, "	40.000	43.560
45, "	45.000	48.920
50, "	50.000	54.330

GRINNELL NO. 5

5.227	.814
10.066	.743
19.378	.730
33.585	.735
46.956	.726
58.470	.726
67.935	.734
73.379	.752
76.835	.743
79.320	.743

1. 488
2. 935
3. 470
4. 520

GRINNELL NO. 6

5.129	.758
10.014	.713
16.168	.715
19.391	.710
22.233	.707
26.739	.700
32.345	.696
37.705	.705
43.120	.708
48.536	.711
53.950	.713

404
744
1,168
1,401
1,673
1,889
2,345
2,795
3,120
3,536
3,930

MINERATION			Gallons/5 Minutes	Calcs./50x Minutes
1st.	2nd.	3rd.	Aver.	
10.4	28.6	36.8	26.43	13.31
30.3	36.2	56.0	36.13	18.06
45.1	44.7	44.9	44.90	22.45
49.2	49.0	49.3	49.16	24.58
53.8	53.1	53.8	53.53	26.81
56.8	57.3	58.9	57.00	28.50
62.3	62.4	62.5	62.40	31.20
68.3	68.6	68.4	68.43	34.31
72.3	72.3	72.0	72.10	36.05
77.9	77.9	---	---	38.95
81.9	82.2	31.4	81.83	40.91

23.0	23.9	27.6	27.86	13.93
35.1	---	---	35.10	17.55
43.1	47.8	48.1	48.00	24.00
53.1	53.2	53.5	53.35	26.63
56.4	56.4	---	56.40	28.30
62.2	61.5	---	61.85	30.92
67.2	67.1	67.3	67.40	33.70
72.1	72.1	72.3	72.25	36.11
77.1	77.1	76.7	76.96	38.48
81.3	81.7	81.5	81.63	40.81

24.8	25.1	25.1	25.00	12.50
34.1	33.8	34.0	33.95	16.98
42.6	42.6	42.3	42.50	21.25
46.7	45.6	45.5	45.50	23.30
50.5	51.1	51.0	50.86	25.43
54.2	53.8	54.4	54.13	27.05
58.9	59.2	59.0	59.03	29.51
65.0	64.3	65.0	64.73	32.33
69.6	69.4	69.7	69.55	34.78
73.9	74.1	74.0	74.00	37.00
78.1	78.2	77.8	78.03	39.01

MANUFACTURERS HEAD NO. (experimental)

DISCHARGE				PRESSURE			Coefficients of Discharge.
Gallons/2 1st. 2nd.	Aver.	Gals. per Minute	Gauge	Ibs. per sq. in.	Velocity lbs/sq. in.	True lbs/sq. in.	
31.2	31.0	31.10	15.55	10.4 wgs.	4.73	.625	.886
41.1	41.3	41.15	30.57	29.0" "	13.18	1.093	.730
47.3	47.7	47.50	33.75	38.1" "	17.76	1.457	.717
53.6	53.3	53.40	36.70	48.3" "	33.40	1.840	.717
60.7	60.8	60.75	30.37	30 lbs.	30.00	2.380	.706
66.1	66.3	66.20	33.10	35 "	35.00	2.830	.712
70.0	70.5	70.25	35.13	40 "	40.00	3.185	.707
74.9	75.0	74.95	37.47	45 "	45.00	3.630	.711
79.4	79.0	79.20	39.60	50 "	50.00	4.050	.713

DISCHARGE

Gallons/2 Minutes		Gals. per Minute	
1st.	2nd.	Aver.	Minute
24.3	34.5	24.40	13.20
30.3	30.0	30.15	15.07
40.5	40.8	40.65	30.27
46.9	47.0	46.95	23.47
53.1	53.4	53.25	36.62
61.4	61.4	61.40	30.70
67.0	66.6	66.80	33.40
71.6	70.8	71.20	35.66
76.8	76.8	76.70	38.35
80.4	80.9	80.65	40.32

PRESSURE

lbs. per sq. in.		Velocity lbs/sq. in.		True lbs/sq. in.		Coefficients of Discharge.
Gauge	10.0"Hg.	16.2" "	28.5" "	38.8" "	48.9" "	
	4.54	7.36	12.99	17.62	23.20	.727
				1.061		.706
				1.423		.712
				1.832		.717
				2.435		.713
				3.380		.717
				3.275		.714
				3.794		.725
				4.300		.733

MANUFACTURERS HEAD NO. 2.

32.6	33.6	33.60	11.30
27.7	27.7	27.70	13.85
26.5	26.4	26.45	18.22
42.3	42.1	42.15	51.07
47.3	47.0	47.15	25.57
53.9	53.7	53.80	26.90
53.7	53.3	53.50	29.40
63.4	63.6	63.50	31.75
68.2	66.4	67.35	33.17
70.2	70.1	70.15	35.07

10.0"Hg.	4.54	.330	4.870	.677
16.2" "	7.36	.495	7.855	.653
28.5" "	12.99	.867	13.847	.647
38.8" "	17.62	1.147	18.767	.663
48.9" "	23.20	1.431	23.631	.641
30.1 lbs.	30.00	1.868	31.868	.630
35 " "	35.00	2.232	37.232	.637
40 " "	40.00	2.502	42.502	.643
45 " "	45.00	2.840	47.840	.633
50 " "	50.00	3.175	53.175	.636

MANUFACTURERS HEAD NO. 3.

23.3	23.0	23.10	11.55
28.6	28.6	28.30	14.30
37.8	37.6	37.70	18.85
44.0	43.8	43.90	31.55
49.1	49.5	49.30	34.65
56.7	56.8	56.75	38.57
62.2	61.8	62.00	31.00
65.4	65.4	65.40	33.70
70.0	70.4	70.20	36.10
74.0	74.2	74.10	37.05

10.0"Hg.	4.54	.344	4.884	.692
16.2" "	7.36	.528	7.888	.694
28.5" "	12.99	.918	13.908	.670
38.8" "	17.62	1.242	18.862	.674
48.9" "	23.20	1.570	23.770	.670
30.1 lbs.	30.00	2.077	32.077	.664
35 " "	35.00	2.432	37.432	.671
40 " "	40.00	2.762	42.762	.663
45 " "	45.00	3.180	48.180	.671
50 " "	50.00	3.545	53.545	.670

MANUFACTURERS HEAD NO. 4.

Gauge	PRESSURE		True lbs/sq. in.	Coefficients of Discharge
	lbs. per sq. in.	Velocity lbs/sq. in.		
10" Hg.	4.54	.638	5.178	.913
15.2" "	7.56	.988	8.348	.895
28.6" "	12.99	1.700	14.890	.886
38.8" "	17.82	2.284	19.804	.882
48.9" "	22.20	2.837	25.037	.877
30 lbs.	30.00	3.740	33.740	.866
35 "	35.00	4.100	39.100	.843
40 "	40.00	4.390	44.390	.809
45 "	45.00	4.580	49.580	.790
50 "	50.00	4.825	54.825	.773

MANUFACTURERS HEAD NO. 5.

10.4" Hg.	4.73	.635	5.355	.884
16.7" "	7.59	.963	8.553	.896
29.0" "	13.18	1.640	14.840	.857
39.1" "	17.76	2.334	19.994	.865
49.3" "	22.40	2.790	25.190	.863
30 lbs.	30.00	3.522	33.522	.838
35 "	35.00	3.275	38.275	.766
40 "	40.00	3.522	43.522	.737
45 "	45.00	3.990	49.990	.739
50 "	50.00	4.430	54.430	.739

MANUFACTURERS HEAD NO. 6.

10.4" Hg.	4.73	.381	5.111	.711
16.7" "	7.59	.571	8.161	.689
29.0" "	13.18	.940	14.130	.671
39.1" "	17.76	1.215	18.975	.660
49.3" "	22.40	1.500	23.900	.651
30 lbs.	30.00	2.026	32.026	.655
35 "	35.00	2.402	37.402	.660
40 "	40.00	2.770	43.770	.662
45 "	45.00	3.175	48.175	.668
50 "	50.00	3.633	53.633	.678

DISCHARGE

1st.	2nd.	Gals. per Minute	
		Aver.	Minute
31.4	31.5	31.45	15.72
39.1	39.2	39.15	19.57
51.2	51.3	51.35	25.65
59.5	59.5	59.50	29.75
68.6	68.6	68.60	33.15
76.1	76.1	76.10	36.05
79.7	79.8	79.75	39.67
81.8	81.8	81.80	40.75
84.7	84.8	84.75	42.17
86.5	86.7	86.50	43.35

31.1	31.2	31.15	15.57
38.5	38.7	38.65	19.32
50.3	50.5	50.40	25.20
58.8	58.9	58.85	29.42
66.0	66.5	66.75	32.87
73.9	73.9	73.90	36.95
70.5	71.9	71.20	35.60
73.8	74.0	73.90	36.95
78.7	78.6	78.65	39.32
82.5	83.3	83.90	41.45

24.3	24.3	24.30	12.15
39.9	39.8	39.75	14.87
38.3	38.0	38.15	19.07
43.4	43.4	43.40	21.70
48.3	48.1	48.20	24.10
56.0	56.1	56.05	28.02
61.0	61.0	61.00	30.50
65.4	65.7	65.55	32.77
70.1	70.3	70.15	35.07
75.3	74.7	75.00	37.50

MANUFACTURERS HEAD NO. 7.

PRESSURE

Coefficients
of
Discharge.

DISCHARGE		PRESSURE		Coefficients of Discharge.	
Gallons/3 Minutes	1st. 2nd. Avar.	Gauge	lbs. per sq. in.	True	Discharge.
26.2	26.2	10.4 Hg.	4.73	5.173	.762
31.8	31.7	16.7 " "	7.59	8.540	.730
39.8	40.0	29.0 " "	13.18	14.308	.700
46.2	46.4	39.1 " "	17.76	19.150	.701
51.8	51.4	49.3 " "	22.40	24.118	.696
59.3	59.4	55.1 lbs.	35.00	38.104	.743
73.9	74.0	45 " "	40.00	43.526	.740
79.1	78.7	45 " "	45.00	48.040	.745
83.8	84.0	50 " "	50.00	54.540	.751

MANUFACTURERS HEAD NO. 8.

DISCHARGE		PRESSURE		Coefficients of Discharge.	
Gallons/3 Minutes	1st. 2nd. Avar.	Gauge	lbs. per sq. in.	True	Discharge.
31.6	31.6	10.4 Hg.	4.73	5.374	.903
39.3	39.5	15.7 " "	7.59	8.535	.889
51.2	51.2	29.0 " "	13.18	14.873	.879
59.3	59.3	39.1 " "	17.76	20.023	.875
66.6	66.4	49.3 " "	22.40	25.155	.876
76.2	---	50 lbs.	35.00	33.750	.867
82.0	---	35 " "	35.00	36.340	.865
86.2	86.7	40 " "	40.00	44.835	.854
91.0	91.0	45 " "	45.00	50.345	.843
94.4	94.8	50 " "	50.00	58.775	.837

MANUFACTURERS HEAD NO. 9.

DISCHARGE		PRESSURE		Coefficients of Discharge.	
Gallons/3 Minutes	1st. 2nd. Avar.	Gauge	lbs. per sq. in.	True	Discharge.
31.7	31.8	10.4 Hg.	4.73	5.330	.859
39.4	39.1	15.7 " "	7.59	8.535	.881
51.2	51.2	29.0 " "	13.18	14.873	.873
59.1	59.2	39.1 " "	17.76	20.015	.863
66.1	66.0	49.3 " "	22.40	25.118	.865
75.9	76.1	50 lbs.	30.00	33.735	.860
81.7	81.8	35 " "	35.00	39.320	.857
85.7	85.6	40 " "	40.00	44.740	.841
88.0	---	45 " "	45.00	50.100	.825
91.9	92.0	50 " "	50.00	56.480	.811

MANUFACTURERS HEAD NO. 10.

DISCHARGE			Gals. per Minute
Lat.	Long.	Aver.	
33.2	33.2	32.30	16.10
39.7	36.7	39.76	15.85
51.4	51.5	51.45	15.72
59.7	59.5	59.55	15.82
65.5	---	65.50	27.75
63.7	63.6	63.65	31.82
69.6	69.9	69.75	34.87
73.7	73.5	73.50	36.90
78.5	78.3	78.30	39.30
83.5	83.3	83.55	41.33

Coefficients
of
Discharge.

Gauge	sq. in.	lbs. per sq. in.	True lbs/sq. in.
10.4"Hg.	4.73	.659	5.356
16.7" "	7.59	1.018	8.568
29.0" "	13.18	1.707	14.887
39.1" "	17.76	2.397	20.057
49.3" "	23.40	2.990	24.390
30 lbs.	30.00	3.615	32.615
35 "	35.00	3.140	38.140
40 "	40.00	3.500	43.500
45 "	45.00	3.890	48.890
50 "	50.00	4.410	54.410

MANUFACTURERS HEAD NO. 11.

33.4	35.4	33.40	11.70
39.0	39.1	39.05	14.52
37.5	37.5	37.55	18.77
42.9	43.1	43.00	21.50
48.6	48.6	48.55	24.37
55.9	55.8	55.85	27.92
60.8	60.5	60.70	30.35
64.4	64.3	64.35	33.17
68.7	68.7	68.70	34.35
72.4	72.5	72.50	36.25

10.4"Hg.	4.73	.354	5.084
16.7" "	7.59	.544	8.134
29.0" "	13.18	.910	14.090
39.1" "	17.76	1.195	18.955
49.3" "	23.40	1.523	25.923
30 lbs.	30.00	2.013	33.013
35 "	35.00	2.378	37.378
40 "	40.00	2.670	42.670
45 "	45.00	2.875	47.875
50 "	50.00	3.398	53.398

MANUFACTURERS HEAD NO. 12.

26.8	26.7	26.75	13.37
33.4	33.3	33.35	16.57
43.8	43.8	43.80	21.40
49.4	49.5	49.45	24.72
55.4	55.3	55.35	27.57
63.5	63.3	63.40	31.70
69.0	69.0	69.00	34.50
73.9	74.0	73.95	36.97
78.2	78.3	78.25	39.12
82.7	82.8	82.75	41.37

10.4"Hg.	4.73	.452	5.192
16.7" "	7.59	.718	8.308
29.0" "	13.18	1.183	14.363
39.1" "	17.76	1.578	19.338
49.3" "	23.40	1.980	24.380
30 lbs.	30.00	2.592	32.592
35 "	35.00	3.075	38.075
40 "	40.00	3.525	43.525
45 "	45.00	3.950	48.950
50 "	50.00	4.420	54.420

.775	.775
.764	.764
.748	.748
.744	.744
.715	.715
.754	.754
.739	.739
.759	.759
.740	.740
.741	.741

MANUFACTURERS HEAD NO. 13.

Pressure

DISCHARGE			Gals. per Minute
1st.	3rd.	Aver.	
32.3	32.2	32.25	16.12
39.8	40.0	39.90	19.95
51.7	53.0	51.85	25.88
60.2	59.7	59.95	29.87
66.5	66.8	66.65	33.33
70.6	76.4	73.50	36.25
75.4	76.5	75.45	38.22
77.3	77.0	77.10	38.55
80.7	80.4	80.55	40.37
85.0	84.8	84.90	42.45

Pressure

Gauge	sq. in.	lbs. per sq. in.	True lbs. per sq. in.
10.4"Hg.	4.73	.679	5.402
15.7" "	7.59	1.039	8.619
29.0" "	13.18	1.733	14.013
39.1" "	17.76	2.316	20.078
48.3" "	22.40	2.845	25.245
50 lbs.	30.00	3.730	33.780
55 " "	35.00	3.750	38.750
40 " "	40.00	3.836	43.836
45 " "	45.00	4.180	49.180
50 " "	50.00	4.650	54.650

Coefficients of

Discharge.
.913
.894
.885
.881
.871
.864
.868
.766
.755
.755

MANUFACTURERS HEAD NO. 14.

32.4	32.5	32.45	16.23
40.1	39.8	39.95	19.97
51.7	51.7	51.70	25.85
59.8	60.0	59.90	29.89
66.1	66.2	66.15	33.07
77.1	77.2	77.15	38.57
78.4	78.6	78.50	39.25
79.2	79.1	79.15	39.57
80.9	81.3	81.10	40.55
85.0	85.2	85.10	42.55

10.4"Hg.	4.73	.679
16.7" "	7.59	1.030
29.0" "	13.18	1.725
39.1" "	17.76	2.316
48.3" "	22.40	2.825
50 lbs.	30.00	3.838
55 " "	35.00	3.978
40 " "	40.00	4.040
45 " "	45.00	4.245
50 " "	50.00	4.675

.932
.900
.886
.885
.871
.877
.832
.788
.764
.750

5.409
8.620
14.202
20.076
25.225
33.856
39.578
44.040
49.245
54.675

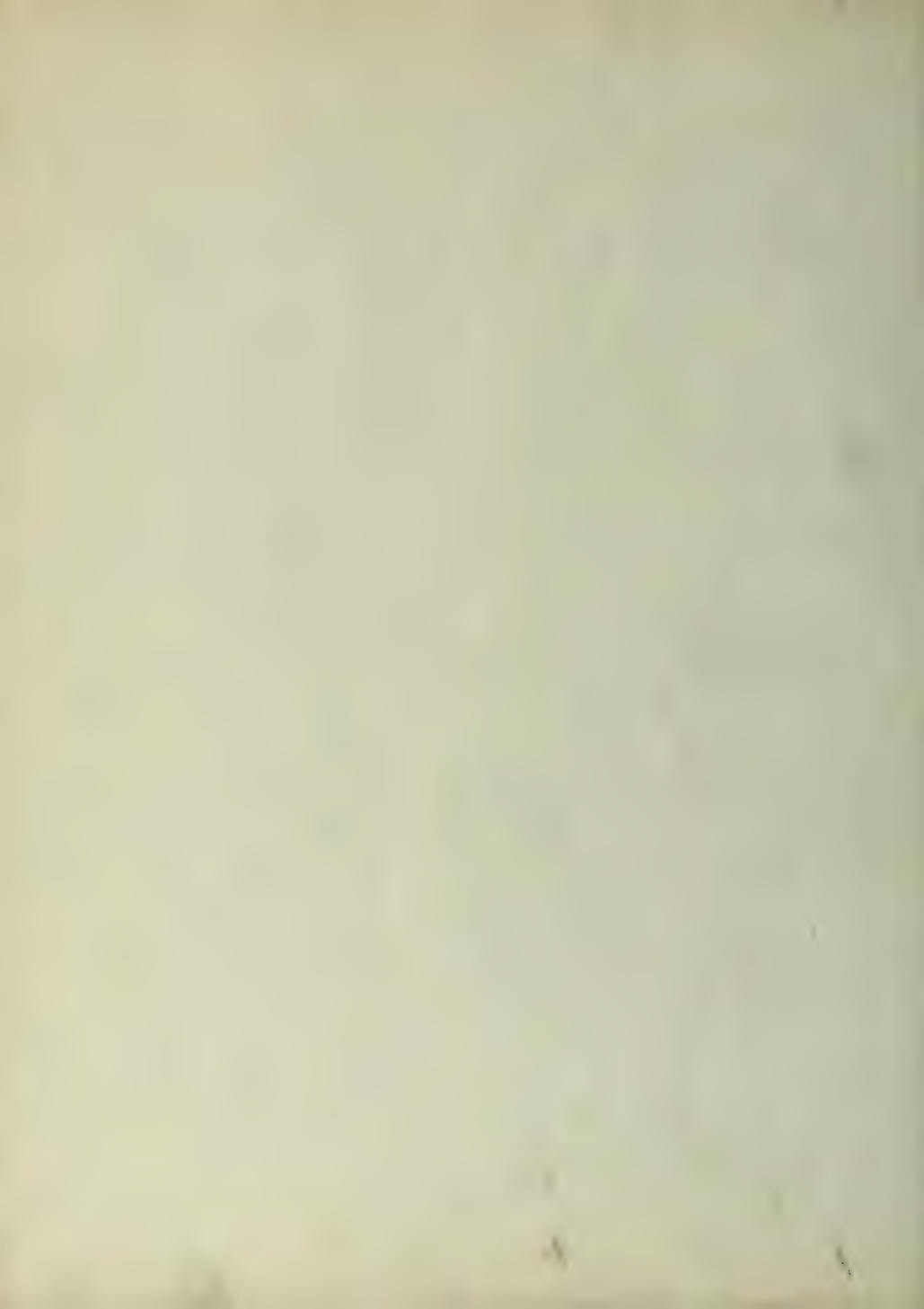
MANUFACTURERS HEAD NO. 15.

32.4	32.5	32.45	15.23
40.3	40.1	40.25	20.12
52.0	52.2	52.10	25.05
60.3	60.2	60.25	30.13
67.0	67.0	67.00	33.50
77.1	77.1	77.10	38.55
82.0	83.1	82.95	41.47
88.0	87.7	87.85	42.82
91.3	91.6	91.25	45.68
94.9	95.0	94.95	47.47

10.4"Hg.	4.73	.679
15.7" "	7.59	1.450
29.0" "	13.18	1.753
39.1" "	17.76	2.340
48.3" "	22.40	2.900
50 lbs.	30.00	3.856
55 " "	35.00	4.440
40 " "	40.00	4.980
45 " "	45.00	5.375
50 " "	50.00	5.820

.922
.882
.893
.888
.881
.876
.873
.866
.845
.839

5.409
9.040
14.922
20.199
25.306
33.856
39.440
44.980
50.375
55.840



MANUFACTURERS HEAD NO. 15.

DISCHARGE

Gal. per Minute	ft. 2nd.	3rd.	4th.
16.02	32.1	33.65	35.1
19.92	39.8	39.85	41.6
25.77	51.6	51.6	53.7
29.85	59.7	59.7	62.1
33.95	66.1	66.1	68.5
38.25	76.3	76.3	78.5
41.05	82.2	82.2	84.8
43.42	88.8	88.8	90.7
45.42	90.7	90.7	94.2
47.15	94.2	94.2	

MANUFACTURERS HEAD NO. 17.

16.00	32.0	33.60	35.1
18.85	39.8	39.70	41.6
25.80	51.2	51.20	53.7
29.55	59.2	59.15	62.1
33.07	66.2	66.15	68.5
37.85	76.5	76.70	78.5
41.05	82.2	82.10	84.8
43.53	87.2	87.05	90.7
45.67	91.2	91.35	94.2
47.60	95.2	95.30	

MANUFACTURERS HEAD NO. 18.

13.20	26.4	26.40	28.1
18.10	33.2	33.20	35.1
20.85	41.5	41.80	43.0
24.05	48.8	48.10	51.6
27.00	54.0	54.00	59.7
30.85	61.6	61.70	66.1
33.85	67.2	67.30	71.3
35.67	71.4	71.35	75.2
38.17	76.5	76.65	80.6
40.20	80.2	80.40	

Range	lbs. per sq. in.	Velocity lbs./sq. in.	True lbs./sq. in.	Coefficient of Discharge
10.4" Hg.	4.73	.863	5.393	.914
16.7" "	7.59	1.026	8.215	.898
29.0" "	13.18	1.715	14.895	.882
39.1" "	17.76	3.300	20.080	.871
49.3" "	22.40	3.830	25.330	.865
30 lbs.	30.00	3.780	33.780	.859
35 "	35.00	4.350	39.350	.847
40 "	40.00	4.860	44.860	.835
45 "	45.00	5.325	50.325	
50 "	50.00	5.725	55.725	

5.391	.904
8.208	.898
14.874	.878
20.015	.874
25.325	.871
33.702	.862
39.350	.865
44.860	.859
50.390	.850
55.855	.832

5.180	.763
8.260	.748
14.314	.734
19.855	.736
24.233	.724
32.460	.716
37.925	.723
43.338	.715
48.760	.723
54.170	.722

MANUFACTURERS HEAD NO. 19.

PRESSURE

DISCHARGE			Gals. per Minute
1st.	2nd.	Aver.	
32.8	32.7	32.75	16.37
40.4	40.4	40.40	20.20
53.3	53.3	53.30	26.15
60.8	60.8	60.80	30.40
67.4	67.5	67.45	33.72
77.8	78.2	78.00	39.00
84.4	84.2	84.30	42.15
89.4	89.7	89.55	44.77
93.7	93.5	93.60	46.80
98.2	98.4	98.30	49.15

DISCHARGE.			True lbs/sq. in.
1st.	2nd.	Aver.	
5.23	5.23	5.23	5.422
8.04	8.04	8.04	8.643
8.90	8.90	8.90	14.944
8.92	8.92	8.92	20.145
8.80	8.80	8.80	25.335
8.80	8.80	8.80	35.930
8.80	8.80	8.80	39.590
8.76	8.76	8.76	45.175
8.60	8.60	8.60	50.660
8.60	8.60	8.60	55.240

DISCHARGE.			True lbs/sq. in.
1st.	2nd.	Aver.	
5.23	5.23	5.23	5.422
8.04	8.04	8.04	8.643
8.90	8.90	8.90	14.944
8.92	8.92	8.92	20.145
8.80	8.80	8.80	25.335
8.80	8.80	8.80	35.930
8.80	8.80	8.80	39.590
8.76	8.76	8.76	45.175
8.60	8.60	8.60	50.660
8.60	8.60	8.60	55.240

MANUFACTURERS HEAD NO. 20.

35.8	36.7	36.75	13.37
32.8	32.9	32.85	15.42
42.8	42.8	42.80	21.40
48.8	48.9	48.85	24.42
55.0	55.1	55.05	27.52
63.2	63.4	63.15	31.57
68.5	68.1	68.30	34.15
73.3	73.4	73.35	36.67
77.5	77.5	77.55	38.77
82.2	82.4	82.30	41.15

10.4"Hg.	4.73	.462
16.7" "	7.59	.696
29.0" "	13.18	1.183
39.1" "	17.76	1.541
49.3" "	22.40	1.953
30 lbs.	30.00	2.570
35 " "	35.00	3.100
40 " "	40.00	3.457
45 " "	45.00	3.880
50 " "	50.00	4.365

5.192	.772
8.286	.753
14.363	.744
19.301	.732
24.353	.734
32.570	.727
38.100	.731
43.475	.733
48.580	.701
54.565	.732

MANUFACTURERS HEAD NO. 21.

33.4	33.4	33.40	15.20
40.0	40.0	40.00	20.00
51.6	51.9	51.75	25.87
59.9	59.9	59.90	29.90
66.8	66.7	66.90	33.45
76.7	76.8	76.75	36.37
83.8	82.8	82.80	41.40
88.2	88.4	88.30	44.15
92.4	92.4	92.40	46.20
96.2	96.2	96.20	48.10

10.4"Hg.	4.73	.578
16.7" "	7.59	1.033
29.0" "	13.18	1.729
39.1" "	17.76	2.308
49.3" "	22.40	2.892
30 lbs.	30.00	3.800
35 " "	35.00	4.435
40 " "	40.00	5.040
45 " "	45.00	5.520
50 " "	50.00	5.995

5.408	.916
8.623	.896
14.909	.883
20.069	.878
25.292	.876
33.800	.868
39.435	.868
45.040	.864
50.520	.853
55.990	.845

MANUFACTURERS HEAD NO. 32.

DISCHARGE				PRESSURE			Coefficients of Discharge.
Gallons/2 Minutes	Aver.	Gals. per Minute	Gauge	lbs. per sq. in.	Velocity lbs./sq. in.	True lbs./sq. in.	
32.4	32.4	32.40	10.4 Hg.	4.73	.678	5.408	.915
39.8	39.9	39.85	15.7 " "	7.59	1.037	8.617	.892
51.3	51.7	51.50	29.0 " "	13.18	1.710	14.890	.878
59.5	59.5	59.50	39.1 " "	17.76	2.285	20.045	.875
64.1	64.2	64.15	49.3 " "	22.40	2.560	25.060	.843
66.4	66.4	66.40	50 lbs.	30.00	2.850	32.850	.702
69.1	69.1	69.10	35 " "	35.00	3.082	38.082	.736
73.4	73.9	73.65	40 " "	40.00	3.502	43.502	.734
78.5	78.8	78.65	45 " "	45.00	3.990	48.990	.738
83.1	83.1	83.10	50 " "	50.00	4.460	54.460	.736

Grinnell Heads.

Head	Orifice	Inlet Diameter.
Standard-----	.499"	.515"
#1 -----	"	.537"
2 -----	"	.595"
3 -----	"	.532"
4 -----	"	.570"
5 -----	"	.625"
6 -----	"	.717"
7 -----	"	.690"

MANUFACTURERS HEAD.

Head	A	B	C	D
Standard-----	.503"	.566"	1.223"	.210"
#1 -----	.503"	.565"	1.220"	.210"
2 -----	.503"	.690"	1.272"	.210"
3 -----	.503"	.630"	1.220"	.210"
4 -----	.503"	.567"	1.220"	.589"
5 -----	.504"	.565"	1.220"	.403"
6 -----	.503"	.598"	1.220"	.202"
7 -----	.503"	.532"	1.220"	.210"
8 -----	.503"	.565"	1.220"	.852"
9 -----	.504"	.566"	1.220"	.655"
10 -----	.504"	.565"	1.222"	.273"
11 -----	.503"	.662"	1.231"	.210"
12 -----	.503"	.565"	1.221"	.158"
13 -----	.504"	.565"	1.220"	.473"
14 -----	.503"	.566"	1.221"	.551"
15 -----	.503"	.567"	1.220"	.764"
16 -----	.503"	.566"	1.220"	.721"
17 -----	.503"	.567"	1.222"	.908"
18 -----	.503"	.565"	1.220"	.213"
19 -----	.504"	.567"	1.220"	1.034"
20 -----	.504"	.566"	1.221"	.096"
21 -----	.504"	.568"	1.220"	.965"
22 -----	.504"	.566"	1.221"	.343"

